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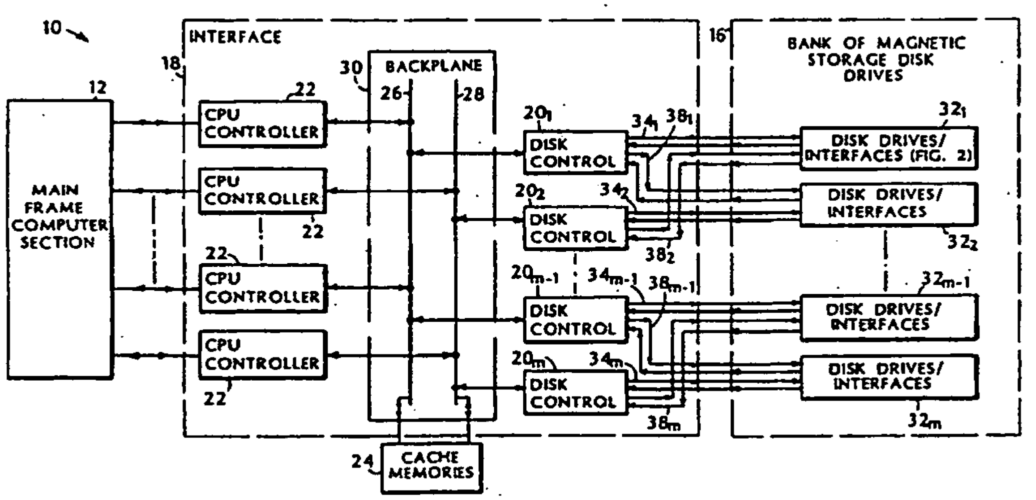

(57) Abstract

A data storage system (10) is a provided wherein each one of a plurality of disk interfaces (32) is coupled to a corresponding storage disk drive (40). The disk interfaces (32) in one portion are coupled through a first unidirectional channel (34) to a first disk controller (20_1) and the disk interfaces (32) in another portion of the disk interfaces are coupled through a second unidirectional channel (28) to a second disk controller (20_2). Each disk interface includes (32) a switch (42) adapted to allow data to pass to another disk drive (40) in the channel (42) thereof; and, when the other channel becomes inoperative, coupling the disk drive (40) in the inoperative channel to the operative fiber channel. With such arrangement, a disk drive may be removed without requiring a shut-down of the storage system (i.e., the disk drive may be "hot swapped"). In one embodiment, a pair of the switches is disposed on the common printed circuit board (43) with the disk interface for enabling depopulation, or removal of, disk drives from the storage system.

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DATA STORAGE SYSTEM

Background of the Invention

This invention relates generally to data storage systems and more particularly to data storage systems having a plurality of magnetic storage disk drives in a redundancy arrangement whereby the disk drives are controllable by primary disk controllers and secondary disk controllers. Still more particularly, the invention also relates to systems of such type wherein the disk drives are coupled to the disk controllers through a series, unidirectional, "ring" or, fiber channel protocol, communication system.

As is known in the art, in one type of data storage system, data is stored in a bank of magnetic storage disk drives. Each one of the disk drives is coupled to a corresponding disk interface. The disk interface is a printed circuit board having a programmable array logic (PAL) circuit for decoding address signals fed to it by a disk controller. When the PAL detects its address, it produces a signal to activate a relay and thereby turn its disk drive "on". The PAL is also used to turn its LED "on" when the disk drive needs to be replaced.

The disk drives, and their coupled interfaces, are arranged in sets, each set being controlled by a primary disk controller and a secondary disk controller. More particularly, in order to enable the set of disk drives to operate in the event that there is a failure of the primary disk controller, each set is also coupled to a secondary, or redundant disk controller. Therefore, if either the primary or secondary disk controller fails, the set can be accessed by the other one of the disk controllers.

While today, most disk storage systems of this type use a Small Computer System Interconnection (SCSI) protocol, in order to operate with higher data rates, other protocols are being introduced. One higher data rate protocol is sometimes referred to as a fiber channel (FC) protocol. Such FC channel protocol uses a series, unidirectional, "ring" communication system. In order to provide for redundancy, that is, to enable use of the set of disk drives in the event that the primary disk controller fails, as discussed above, the set is coupled to the second, or redundant disk controller, using a separate, independent, "ring", or fiber channel communication protocol. Thus, two fiber channels are provided for each set of disk drives and their disk interfaces; a primary fiber channel and a secondary fiber channel.

As is also known, when using the fiber channel communication protocol, if any element in the channel becomes inoperative, the entire channel becomes inoperative. That is, if the primary disk controller becomes inoperative, or if any one of the disk drives in the set coupled to the primary channel becomes inoperative (i.e., as where the disk interface fails, the disk interface is inoperative, or removed with its coupled disk drive, or where the disk drive coupled thereto fails, or is removed), the primary fiber channel, is "broken", or open, and becomes inoperative. The data stored in the entire portion of the set of disk drives coupled to the primary disk channel is therefore unavailable until the inoperative primary disk controller or inoperative disk drive is replaced. This is true with either the primary channel or the secondary channel. One technique suggested to solve this problem is through the use of a switch, sometimes referred to as an LRC (i.e., a

loop resiliency circuit) switch. Such LRC switch is used to remove an inoperative disk drive from its channel.

In one suggested arrangement, a printed circuit board is provided for each disk drive. The printed circuit board has a pair of LRCs, one for the primary channel and one for the secondary channel. Thus, the open channel may be "closed" in the event of an inoperative disk drive by placing the LRC thereof in a by-pass condition. While such suggested technique solves the inoperative disk drive, or open channel problem, if one of the pair of LRCs fails, the entire printed circuit board having the pair of LRCs must be replaced thereby disrupting both the primary and secondary channels; and, hence, disrupting the operation of the entire data storage system.

One technique suggested to solve this disruption problem requires n LRC switches (where n is the number of disk drives in the set) in the primary channel, i.e., one LRC for each one the n disk drives in the set and another n LRC switches in the secondary channel for each one of the n disk drives in the secondary channel. The primary channel set of n LRCs is mounted on one printed circuit board and the secondary channel set of n LRCs is mounted on a different printed circuit board. A backplane is used to interconnect the two LRC printed circuit boards, the associated multiplexers, and the disk drives. In order to provide the requisite serial, or sequential, fiber channel connections, an elaborate, complex, fan-out wiring arrangement has been suggested for the backplane. Further, the slots provided for the two LRC boards eliminates two disk drives, and the disk interfaces which would otherwise be plugged into these two slots of the backplane.

Summary of the Invention

In accordance with the present invention, a data storage system is provided wherein each one of a plurality of disk interfaces is coupled to a corresponding storage disk drive. A first portion of the disk interfaces is coupled to a first disk controller through a first unidirectional channel and a second portion of the disk interfaces is coupled to a second disk controller through a second unidirectional channel. Each disk interface in the first portion includes a switch adapted to allow address control and data (hereinafter referred to, collectively, as data) to pass though the first channel; and, when the second channel becomes inoperative, couple an operative disk drives in the inoperative second channel to the first channel. With such arrangement, redundancy is provided because if the second disk controller becomes inoperative, the first disk controller is able to store data in and/or retrieve data from the disk drives in the second channel. Further, if one of the disk drives in the second channel is inoperative, all of the other, operative disk drives in the second channel are switched to the first channel, thereby enabling the disk drive to be replaced without having to shut down the operative disk drives in the second channel, i.e., the inoperative disk drive may be "hot swapped".

In accordance with another feature of the invention, the switch is disposed on a common printed circuit board with the disk interface. Thus, the interface and its disk drive are packaged as a module to facilitate maintenance and providing system modularity. With such arrangement a simpler, local (i.e, the disk interface and the switch are located on a common printed circuit board) connecting arrangement is used to interconnect the disk drives and their associated

switches as compared with the complex, fan-out connection arrangement discussed above. Still further, with this arrangement, there is no loss of slots on the backplane.

In accordance with still another feature of the invention, each disk interface includes a pair of the switches. The additional switch enables termination of a channel at a point where additional disk drives are no longer needed. Thus, the second switch enables "depopulation" or removal of a portion of the disk drives in the channel when a such portion is no longer needed by the storage system.

Brief Description of the Drawing

FIG. 1 is a block diagram of a computer system having a data storage system according to the invention;

FIG. 2 is sketch showing how FIGS. 2A and 2B are arranged to make up a block diagram of a set of storage disk drives and their disk interfaces according to the invention, such set being used in the computer system of FIG. 1; and,

FIG. 3 is a block diagram of an exemplary addressable interface used in the disk interfaces of FIG. 2; and

FIG. 4 is a block diagram of a pair of disk drives and their interfaces in accordance with an alternative embodiment of the invention.

Description of the Preferred Embodiments

Referring now to FIG. 1, a computer system 10 is shown. The computer system 10 includes a main frame computer section 12 for processing data. Portions of the processed data are stored in, and retrieved data from, a bank 16 of magnetic storage disk drives through an conventional system interface 18. The system interface 18 includes disk controllers 20_1-20_m, central processor unit (CPU) controllers 22 and cache memories 24 electrically interconnected, in a conventional manner, as

shown, through a pair of buses 26, 28 provided for redundancy in a backplane printed circuit board 30. Thus, disk controllers 20_1, ... 20_{m-1} are coupled to bus 26, and disk controllers 20_2 ... 20_m are coupled to bus 28, as shown. Each one of the disk controllers 20_1-20_m is coupled to a corresponding one of sets 32_1-32_m of the disk drives 40_1-40_n and associated disk interfaces 42_1-42_n, respectively, as shown, through primary fiber channel protocol channels 34_1-34_m, respectively, as shown. Each one of the sets 32_1 - 32_m of disk drives and associated disk interfaces is identical in construction, an exemplary one thereof, here set 32_1 being shown, and discussed in detail, in connection with FIG. 2. Further, each one of the disk controllers 20_1-20_m is coupled to another one of the sets 32_1-32_m of disk drives 40_1-40_n and associated disk interfaces 42_1-42_n through secondary fiber protocol channels 38_1- 38_m, as shown, here indicated by dotted lines. Thus, for example, disk controller 20_1 is coupled to set 32_1 through primary fiber channel 34_1 and is also coupled to set 32_2 through secondary fiber channel 38_1. Likewise, disk controller 20_2 is coupled to set 32_2 through primary fiber channel 34_2 and is also coupled to set 32_1 through secondary fiber channel 38_2, as shown. Thus, while set 32_1 is, during normal mode of operation, coupled through disk controller 20_1 to bus 26, in the event that disk controller 20_1 becomes inoperative, set 32_1 is coupled to bus 28 through disk controller 20_2. Finally, it should be noted that the cache memories 24 are coupled to both buses 26 and 28, in a conventional manner.

Referring now also to FIG. 2, an exemplary one of the plurality of sets 32_1-32_m, here set 32_1 of disk drives 40_1-40_n and associated disk interfaces 42_1-42_n, is shown. Each one of the disk interfaces 42_1-42_n is adapted to control a corresponding one of the magnetic storage disk

drives 40_1-40_n coupled thereto, respectively, as shown. In normal mode of operation, data passes from the disk controller 20_1 (FIG. 1) sequentially through the disk interfaces 42_1, 42_3, ... 42_{n-3}, 42_{n-1} (and hence through the disk drives 40_1, 40_3, ... 40_{n-3}, 40_{n-1} coupled thereto), via the primary fiber channel 34_1; and, data passes from the disk controller 20_2 sequentially through the disk interfaces 42_2, 42_4, ... 42_{n-2}, 42_n (and hence through the disk drives 40_2, 40_4, ... 40_{n-2}, 40_n coupled thereto), via the secondary fiber channel 38_1, as indicated by the dotted lines.

More particularly, the disk interfaces 42_1-42_n are arranged in groups, or cells, 43_1-43_p; here groups of two (i.e., pairs) of successive disk interfaces; thus, here $p=n/2$. Thus, pairs of disk interfaces 42_1, 42_2; 42_3, 42_4; ... 42_{n-1}, 42_n, and their associated disk drives 40_1, 40_2; 40_3, 40_4; ... 40_{n-1}, 40_n, are grouped together to form cells 43_1-$43_{n/2}$, respectively as shown. Each one of the cells 43_1-$43_{n/2}$ is identical in construction, an exemplary one thereof, here cell 43_1 is shown to included disk interfaces 42_1, 42_2, and their coupled disk drives 40_1, 40_2, respectively, as indicated. Each one of the cells 43_1-$43_{n/2}$ has a primary input port PI_1-$PI_{n/2}$, respectively, as shown, and a primary output port PO_1-$PO_{n/2}$, respectively, as shown. Each one of the cells 43_1-$43_{n/2}$ has a secondary input port SI_1-$SI_{n/2}$, respectively, as shown, and a secondary output port SO_1-$SO_{n/2}$, respectively, as shown. The cells 43_1-$43_{n/2}$ are sequentially (i.e. serially) coupled to the controllers 20_1, 20_2 through the fiber channels 34_1, 38_1, respectively, from primary output port PO to primary input port PI, for the primary fiber channel 34_1 and from secondary input port SI to secondary output port SO, for the secondary channel 38_1.

Each one of the disk interfaces 42_1-42_n includes a corresponding one of a plurality of switches 44_1-44_n, as shown. Each one of the switches 44_1-44_n is identical in construction and, here, switches 44_1-44_n are conventional LRC switches. Thus, each one of the switches 44_1-44_n includes a pair of input ports I_1, I_2 and a pair of output ports O_1, O_2, as shown. When one of the switches 44_1-44_n is in the feed-through condition (as indicated by curved arrow B) the data fed to first input port I_1 thereof passes to the first output port O_1 thereof and, likewise, data fed to the second input port I_2 thereof passes to the second output port O_2 thereof; however, when of the switches 44_1-44_n is in the by-pass condition (as indicated by the arrows A), data fed to input port I_1 thereof is diverted from the first output port O_1 thereof and is coupled directly to the second output port O_2 thereof. Each one of the switches 44_1-44_n is placed in either the feed-through condition or the by-pass condition by a control signal fed thereto via control line 46_1-46_n, respectively, as shown.

In the normal mode of operation, primary disk controller 20_1 is coupled, as noted above, to disk drives 40_1, 40_3, ... 40_{n-3}, 40_{n-1}, by primary fiber channel 34_1. Likewise, secondary disk controller 20_2 is coupled to disk drives 40_2, 40_4, ... 40_{n-2}, 40_n through secondary fiber channel 38_1. (It should be noted that while the data is depicted as passing from the disk drives 40 and then to the switches 44, it is preferable that the data passes from the switches 44 and then to the disk drives, i.e., it is preferable that the direction indicated by the arrow in primary channel 34_1 be reversed in direction). Thus, in the normal mode of operation, switch 44_1 is in the by-pass condition, as indicate by the curved arrow A. Thus, data from disk controller 20_1 is fed, via twisted pair 47, to primary input port PI_1 of

cell 43_1 to disk interface 42_1, to disk drive 40_1, then to the first input port I_1 of switch 44_1. Because switch 44_1 is in the by-pass condition by the control signal on control line 46_1, data from disk drive 40_1 passes directly to second output port O_2 and then to primary output port PO_1. From there, the data passes, in like manner, to disk interface 42_3 of the next successive cell 43_2, where the process repeats for disk drive 40_3; and then, in like manner, sequentially through the other cells and to cells $43_{(n/2)-1}$-43_n and then back to the primary controller 20_1 (FIG. 1).

Likewise, in the normal mode of operation, switch 44_2 is in the by-pass condition by a control signal on line 46_2, as indicted by the arrow A and data from disk controller 20_2 (FIG. 1) passes to secondary input port SI_1 of cell 43_1, then from first input port I_1 of switch 44_2 directly to second output port O_2 of switch 44_2. The data then passes from disk drive 40_2 to secondary output port SO_2. From there, the data passes, in like manner, to disk interface 42_4 of the next successive cell 43_2, where the process repeats for disk drive 40_4; and then, in like manner, sequentially through the other cells and to cells $43_{(n/2-1)}$-$43_{n/2}$ and then back to the secondary controller 20_2 (FIG. 1).

If disk controller 20_2 becomes inoperative, for example, an effect which "breaks" the secondary channel "ring", the switches 44_1, 44_3 ... 44_{n-3},44_{n-1} are placed in the feed-through condition by the control signal on line 46_1, 46_3 ... 46_{n-3}, 46_{n-1} and therefore, primary disk controller 20_1 is coupled, via primary fiber channel 34_1, to disk drives 40_1, 40_2, 40_3, 40_4 ... 40_{n-3}, 40_{n-2}, 40_{n-1}, 40_n. More particularly, in such feed-through condition, indicted by the arrows B, data at the first input ports I_1 of switches 44_1, 44_3 ... 44_{n-3}, 44_{n-1} pass directly to first output ports O_1 thereof, and passes to disk drives

40_2, 40_4 ... 40_{n-2}, 40_n, then directly from second input ports I_2 to second output ports O_2 of switches 44_1, 44_3 ... 44_{n-3}, 44_{n-1} to primary channel output ports PO_2 thereby coupling disk interfaces 42_2, 42_4, ... 42_{n-2}, 42_n and their coupled disk drives 40_2, 40_4, ... 40_{n-2}, 40_n to the primary fiber channel 34_1.

On the other hand, if the primary disk controller 20_1 becomes inoperative, for example, an effect which "breaks" the primary channel "ring", the switches 44_2, 44_4 ... 44_{n-2}, 44_n are placed in the feed-through condition and therefore, secondary disk controller 20_2 is coupled, via secondary fiber channel 38_1, to disk drives 40_1, 40_2, 40_3, 40_4 ... 40_{n-3}, 40_{n-2}, 40_{n-1}, 40_n. More particularly, in such feed through condition, disk interfaces 42_1, 42_3, ... 42_{n-3}, 42_{n-1} and their coupled disk drives 40_1, 40_3, ... 40_{n-1}, 40_{n-1} are coupled to the secondary fiber channel 38_1.

If any one of the disk drives 40_2, 40_4, ... 40_{n-2}, 40_n, in the secondary channel 38_1 becomes inoperative thereby breaking the secondary channel 38_1, all other operative disk drives in the secondary channel 38_1 become coupled to the primary channel 34_1. For example, if disk drive 40_2 becomes inoperative, an effect which "breaks" the secondary channel 38_1, switches 44_3 - 44_{n-1} are switched from the by-pass condition to the feed through condition; switch 44_1 remaining in the by-pass condition. Therefore, the primary disk controller 20_1 becomes coupled to disk drives 40_1, 40_3, 40_4, ... 40_{n-3}, 40_{n-2}, 40_{n-1}, and 40_n.

On the other hand, if any one of the disk drives 40_1, 40_3, ... 40_{n-3}, 40_{n-1} in the primary channel 34_1 becomes inoperative, thereby breaking the primary channel 34_1, all other operative disk drives in the primary channel 34_1 become coupled to the secondary channel 38_1. For example, if disk drive 40_3 becomes inoperative, an

effect which "breaks" the primary channel 34_1, switches 44_2, 44_5(not shown), ... 44_{n-2}, and 44_n are switched from the by-pass condition to the feed through condition; switch 44_4 remaining in the by-pass condition. Therefore, the secondary disk controller 20_2 becomes coupled to disk drives 40_1, 40_2, 40_3, 40_5 (not shown), ... 40_{n-3}, 40_{n-2}, 40_{n-1}, and 40_n.

The control signal on line 46_1 is produced by an addressable control section 51_1, shown in FIG. 3 to include a PAL and an OR gate. The addressable control section 51_1 is included in disk interface 42_1. The addressable control section 51_1 is addressable by controller 20_1 (FIG. 1) via a separate control line bus 53_1. More particularly, the bus 53_1 is fed to address the PAL. The addressable control section 51_1 is also fed by a signal on line 57_1 generated by disk interface 42_2 indicating that disk drive 40_2 is inoperative. In response to the signals fed to the addressable control section 51_1 from either disk controller 20_1 on bus 53_1 or the disk interface 42_2 on line 57_1, the addressable control section 51_1 places switch 44_1 in either the feed-through, or alternatively, by-pass condition. More particularly, addressable control section 51_1 places switch 44_1 in the by-pass condition if the disk drive 40_2 is inoperative, as described above (i.e., via the signal on line 57_1, or when disk controller 20_2 becomes inoperative, as described above, via the signals on bus 53_1. In like manner, the control signal on line 46_2 is produced by an addressable control section 51_2 included in disk interface 42_2. The addressable control section 51_2 is addressable by the primary controller 20_2 (FIG. 1) via a separate control bus 53_2 from controller 20_2. The addressable control section 51_2 is also fed by a signal on line 57_2 generated by disk interface 42_2 indicating that disk drive 40_1 is inoperative. In response to the

signals fed thereto from either controller 20_1 on bus 53_2 or the disk interface 42_1 on line 57_2, the addressable control section 51_2 places switch 44_2 in either the feed-through, or alternatively, by-pass condition. More particularly, addressable control section 51_2 places switch 44_2 in the by-pass condition if disk controller 20_1 is inoperative, or if the disk drive 40_1 becomes inoperative, as described above. Addressable control sections 51_3-51_n, are included in the other disk interfaces 42_3-42_n, in a similar manner.

Each one of the switches 44_1-44_n is disposed on a common printed circuit board with a corresponding one of the disk interface, 42_1-42_n, respectively.

Referring now to FIG. 4, an exemplary pair of cells $43'_{(m/2)-1}$, $43'_{m/2}$ is shown, where m is an integer between 1 and n. Cells $43'_{(m/2)-1}$, $43'_{m/2}$ differ from cells 43_1-$43_{n/2}$ described above in connection with FIG. 2 in that each disk interface 42_1, 42_n, includes a second LRC switch 44'. Thus, for the exemplary interfaces $42'_{m-3}$, $42'_{m-2}$, $42'_{m-1}$, such interfaces include switches 44_{m-3}, 44_{m-2}, 44_{m-1} and 44_m, respectively, and switches $44'_{m-3}$, $44'_{m-2}$, $44'_{m-1}$, and $44'_m$, respectively, as shown. Switches 44_{m-3}, 44_{m-2}, 44_{m-1} and 44_m are normally in the by-pass condition as indicated and as described above in connection with FIGs. 1 and 2, while switches $44'_{m-3}$, $44'_{m-2}$, $44'_{m-1}$, and $44'_m$ are normally in the feed-through condition as indicated. Here again the primary fiber channel 34_1 is indicated by the solid line and the secondary fiber channel 38_1 is indicated by the dotted line, as in FIG. 1 and 2. A control signal is fed to switch $44'_{m-3}$ via control line $57'_1$ from disk interface $42'_{m-1}$, as shown. A control signal is fed to switch $44'_{m-2}$ via control line $57'_2$ from disk interface $42'_m$, as shown. Switches $44'_{m-3}$, $44'_{m-2}$, $44'_{m-1}$, and $44'_m$ are provided to enable "depopulation" of disk drives. For

example, if disk drive 40_{m-1} is no longer required by the storage system 10, a control signal is produced on control line $57'_1$ to place switch $44'_{m-3}$ in the by-pass condition thereby making disk drive 40_{m-3} the last disk drive in the primary fiber channel 34. Likewise, if disk drive 40_m is removed, a control signal is produced on control line $57'_2$ to place switch $44'_{m-2}$ in the by-pass condition thereby making disk drive 40_{m-2} the last disk drive in the secondary fiber channel 34. Further, a fiber channel may be terminated at any point by the switches 44'.

Other embodiments are within the spirit and scope of the appended claims.

1. A data storage system, comprising:

a plurality of disk interfaces, each one being adapted to control a storage disk drive coupled thereto, a first portion of the disk interfaces being adapted to receive signals from a first controller through a first channel and a second portion of the disk interfaces being adapted to receive data from a second controller through a second channel, each one of the disk interfaces in the first portion having:

a switch adapted to allow data to pass through the first channel; and, when the second channel becomes inoperative, couple an operative disk drive in the inoperative second channel to the first channel.

2. The data storage system recited in claim 1 each one of the disk interfaces in the second portion has:

a switch adapted to allow data to pass through the second channel; and, when the first channel becomes inoperative, couple an operative disk drive in inoperative first channel to the second channel.

3. A data storage system wherein each one of a plurality of disk interfaces is coupled to a corresponding storage disk drive, a first portion of the disk interfaces being connected sequentially in a first unidirectional channel, to a first disk controller and a second portion of the disk interfaces being coupled to a second controller through a second unidirectional channel:

each one of the first portions of the disk interfaces including a first switch, disposed in the first channel, adapted to allow data to pass to the next sequential disk drive in the first channel; and, when the

second channel becomes inoperative, couple an operative disk drive in second channel to the first channel; and,

each one of the disk interfaces in the second portion including a switch, disposed in the second channel, adapted to allow data to pass to the next sequential disk drive in the second channel; and, when the first channel becomes inoperative, couple an operative disk drives in first channel to the second channel.

4. A method for changing a disk drive in a data storage system, each one of a first portion of disk drives being coupled through a first fiber channel, each one of a second porion of the disk drives being coupled through a secondary fiber channel, each of the disk drives being coupled to a switch, comprising the step of:

operating the switch to remove the disk drive being changed from the first fiber channel and coupling the other disk drives in first fiber channel to the second fiber channel

5. A disk interface adapted for coupling a disk drive to a fiber channel to control the disk drive, such interface having:

an interface input port;

an interface output port;

a switch having a pair of input ports and a pair of output ports, a first one of the pair of switch input ports being serially coupled to the interface through the disk drive, and one of the pair of output ports being coupled to the interface output port, the other one of the pair of input ports and the other one of the pair of output ports being adapted for coupling to another disk interface, such switch, in response to one state of a control signal coupling a first one of the

pair of input ports to a first one of the pair of output ports and a second one of the pair of input ports to a second one of the pair of output ports, and in response to a second state, coupling the first one of the pair of input ports to the second one of the pair of output ports.

6. A disk interface adapted for coupling a disk drive to a fiber channel to control the disk drive, such interface having:

an interface input port;

an interface output port;

a first switch having a pair of input ports and a pair of output ports, such first switch, in response to one state of a control signal coupling a first one of the pair of input ports to a first one of the pair of output ports and a second one of the pair of input ports to a second one of the pair of output ports, and in response to a second state, coupling the first one of the pair of input ports to the second one of the pair of output ports;

a second switch having a pair of input ports and a pair of output ports, such second switch, in response to one state of a control signal coupling a first one of the pair of input ports to a first one of the pair of output ports and a second one of the pair of input ports to a second one of the pair of output ports, and in response to a second state, coupling the first one of the pair of input ports to the second one of the pair of output ports;

a first one of the pair of first switch input ports being serially coupled to the interface through the disk drive;

one of the pair of first switch output ports being coupled to a first one of the pair of second switch input ports;

a first one of the second switch output ports being coupled to the interface output port;

the other one of the pair of first switch input ports and the other one of the pair of first switch output ports being adapted for coupling to another disk interface; and,

the other one of the pair of second switch input ports and the other one of the pair of second switch output ports being adapted for coupling to the fiber channel.

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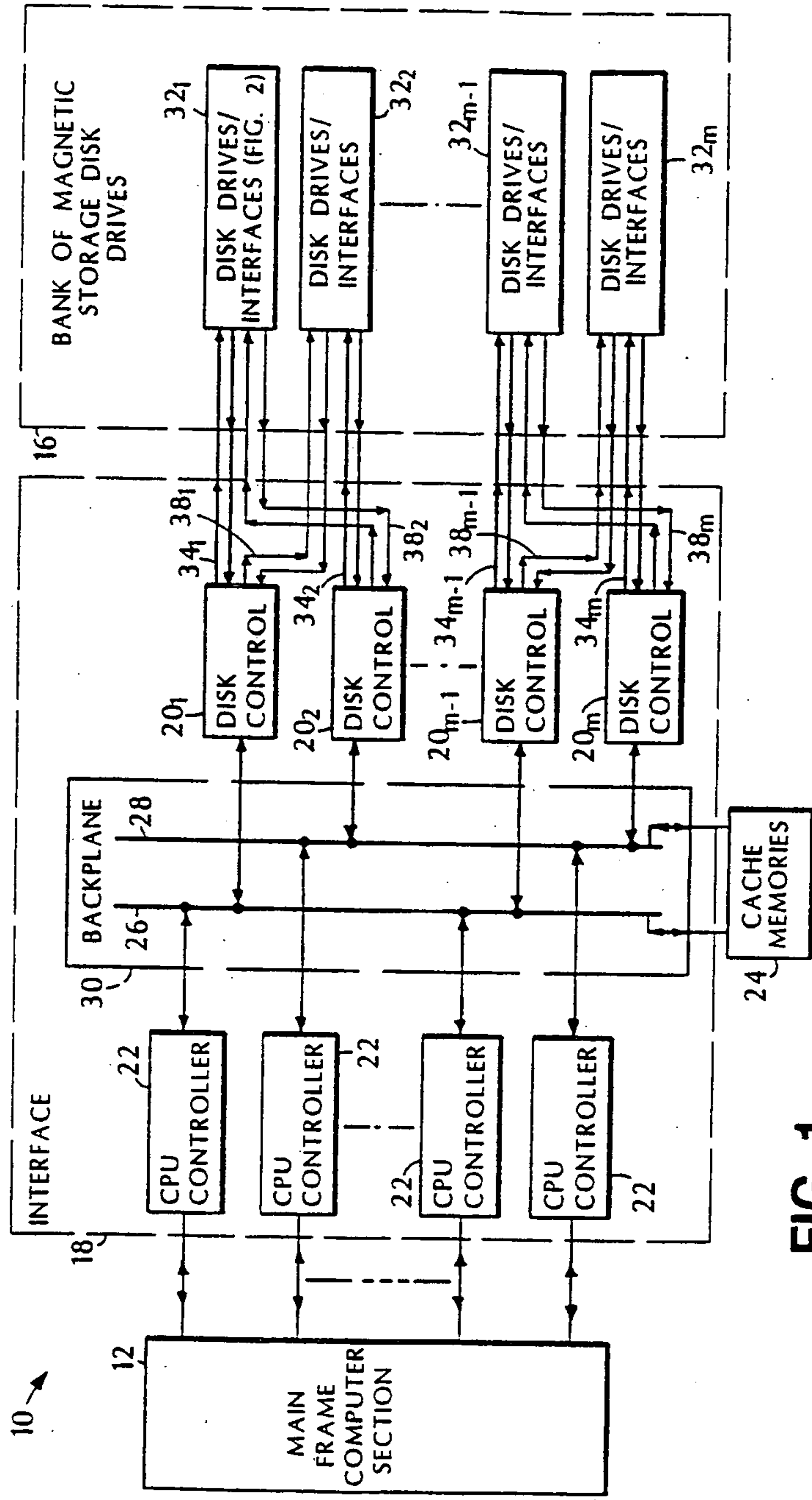

BANK OF MAGNETIC STORAGE DISK DRIVES
DISK DRIVES/ INTERFACES (FIG. 2)
DISK DRIVES/ INTERFACES
DISK DRIVES/ INTERFACES
DISK DRIVES/ INTERFACES
INTERFACE
DISK CONTROL
DISK CONTROL
DISK CONTROL
DISK CONTROL
BACKPLANE
CACHE MEMORIES
CPU CONTROLLER
CPU CONTROLLER
CPU CONTROLLER
CPU CONTROLLER
MAIN FRAME COMPUTER SECTION
10
12
16
18
22
24
26
28
30

FIG. 1

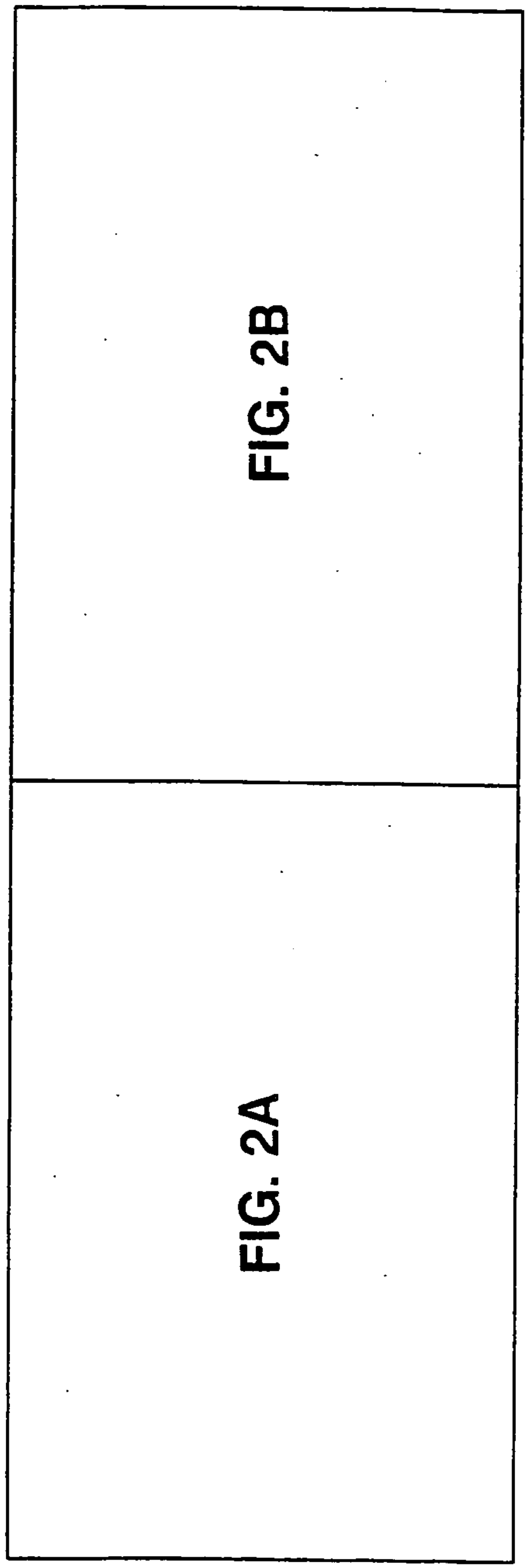


FIG. 2B
FIG. 2A

FIG. 2

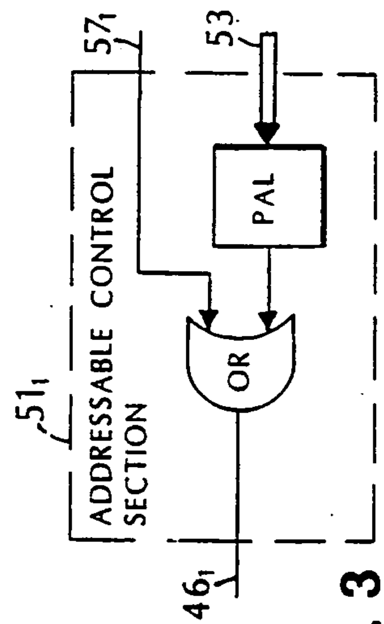

57_1
53
PAL
OR
51_1
ADDRESSABLE CONTROL SECTION
46_1

FIG. 3

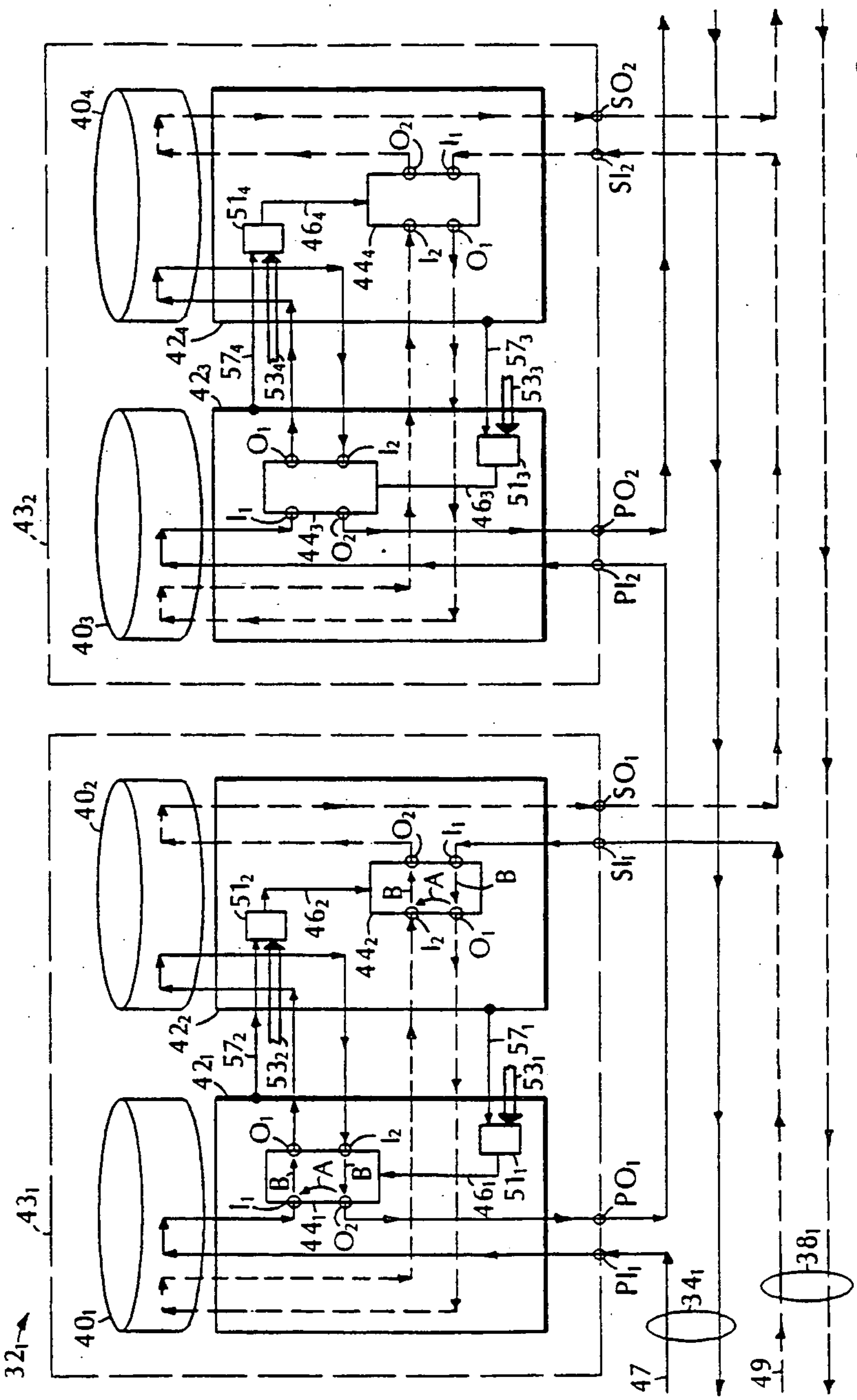


FIG. 2A

SUBSTITUTE SHEET (RULE 26)

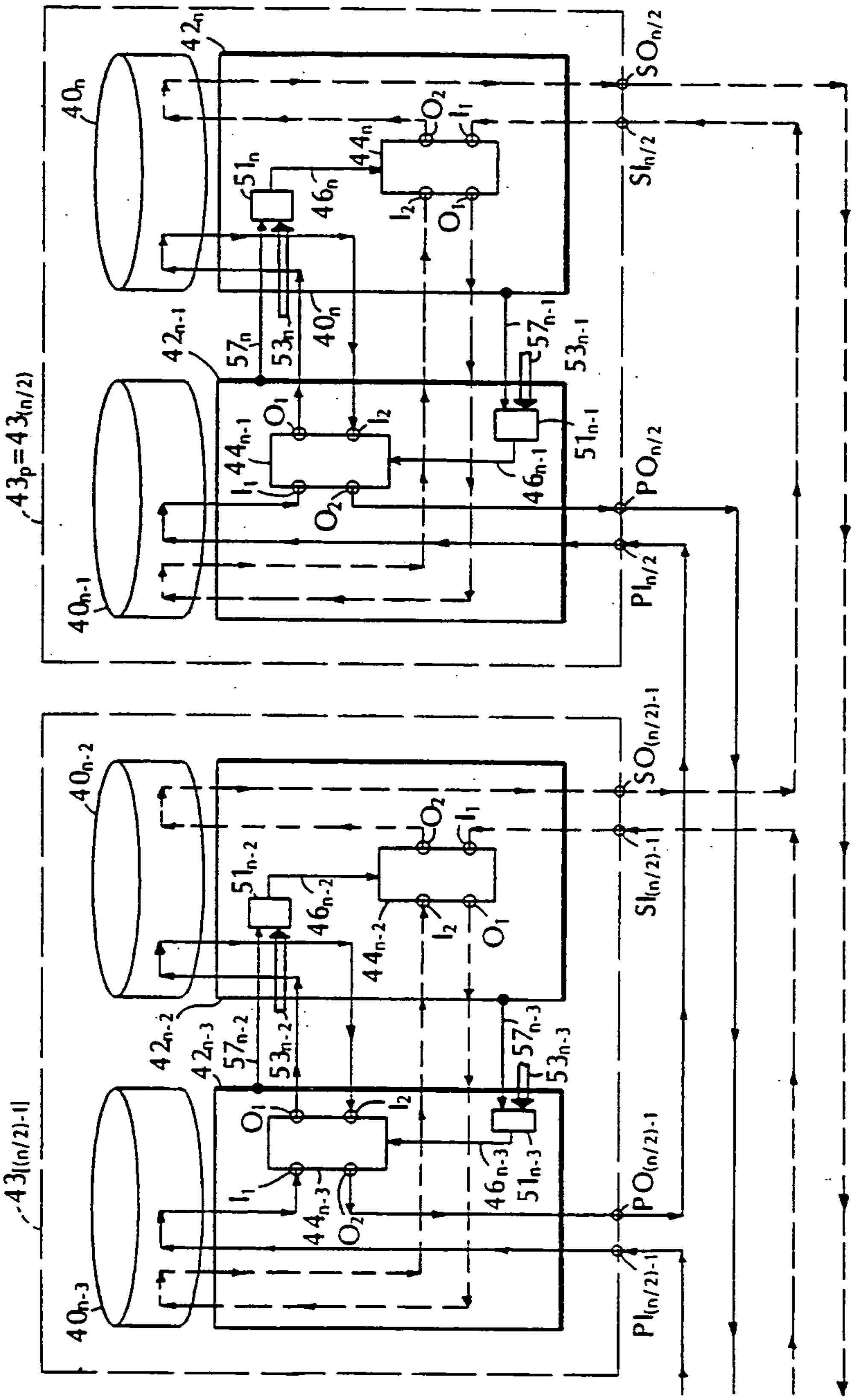
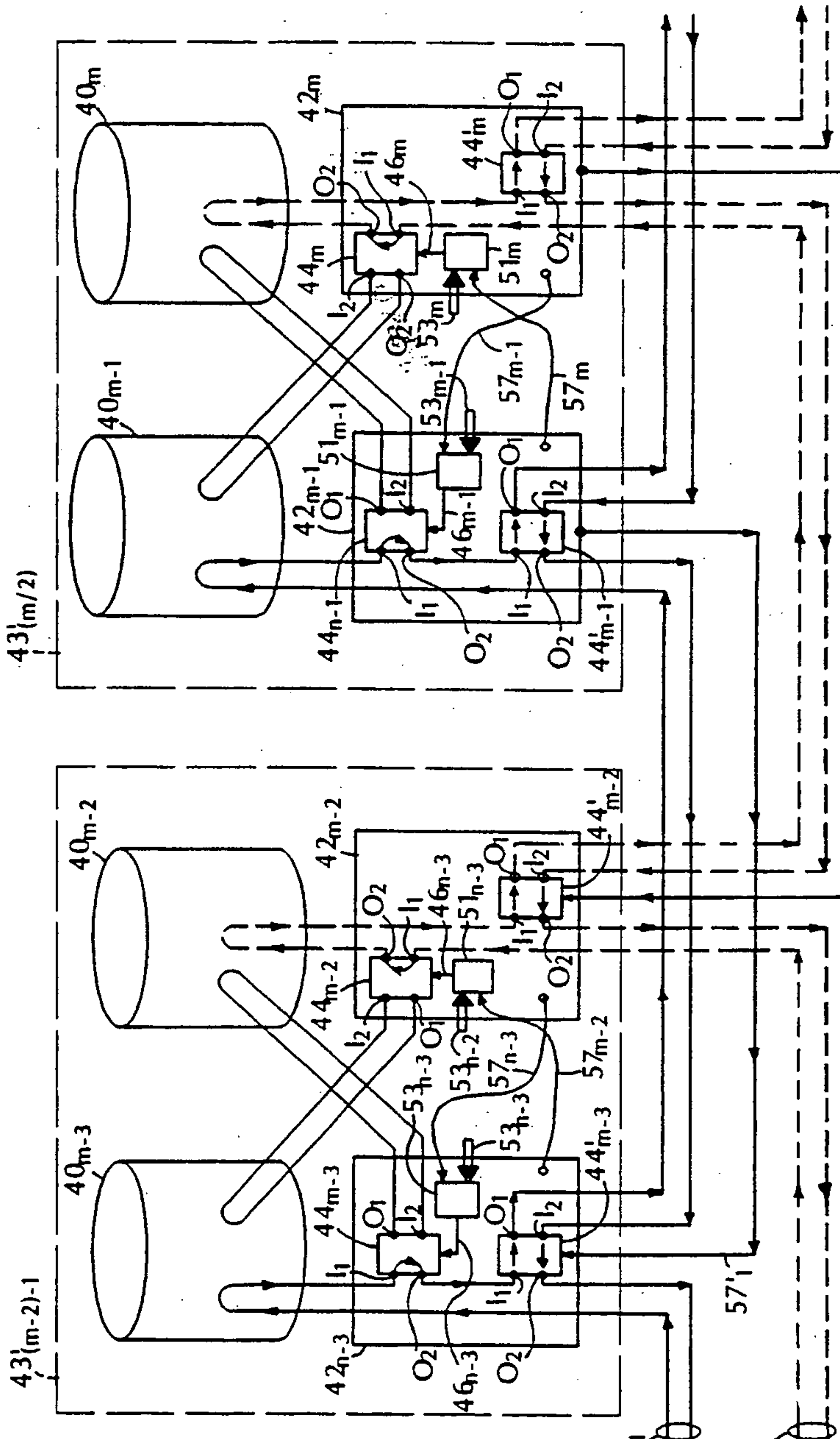


FIG. 2B

SUBSTITUTE SHEET (RULE 26)



40m
42m
44m
44'm
46m
51m
53m
57m
57m-1
40m-1
42m-1
44m-1
44'm-1
46m-1
51m-1
53m-1
43'(m/2)
40m-2
42m-2
44m-2
44'm-2
46n-3
51n-3
53n-2
57n-3
57m-2
40m-3
42n-3
44m-3
44'm-3
46n-3
53n-3
57'1
57'2
43'(m-2)-1
34₁
38₁
O1
O2
I1
I2

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US96/13172

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :G06F 11/10
US CL :395/180, 181, 182, 441, 858; 371/10.1
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 395/180, 181,182, 441, 858; 371/10.1

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US, A, 5,077,736 (DUNPHY, JR. ET AL.) 31 December 1991, See Entire Document	1-6

☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be part of particular relevance

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"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
24 SEPTEMBER 1996	11 OCT 1996

Name and mailing address of the ISA/US	Authorized officer
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